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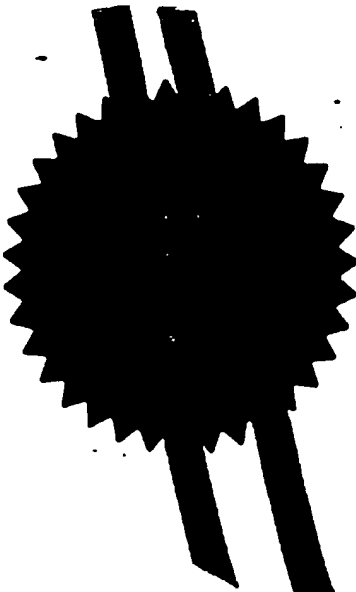
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Patents ADP number (if you know it)			
If the applicant is a corporate body, give the country/state of its incorporation	UNITED KINGDOM	3998564001	
4. Title of the invention	ASSAY METHOD		
5. Name of your agent (if you have one)	STEVENS HEWLETT & PERKINS		
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Patents ADP number (if you know it)	1545003		
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7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	Number of earlier application	Date of filing (day / month / year)	
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Description	10
Claim(s)	2
Abstract	
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Translations of priority documents

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Request for preliminary examination and search (Patents Form 9/77)

Request for substantive examination (Patents Form 10/77)

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11. I/We request the grant of a patent on the basis of this application.

Signature Steen Hewlett & Perkins Date 25-11-96

Agents for the Applicant

12. Name and daytime telephone number of person to contact in the United Kingdom

P Pennant; 0171-936-2499

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ASSAY METHOD

5 This invention is concerned with a method of assaying for
activated peptide-specific T-cells. It is an adaptation of the known
ELISPOT assay, which is reviewed in current protocols in Immunology,
Unit 6.19, pages 6.19.1-8.

10 The filter immunoplaque assay, otherwise called the enzyme-
linked immunospot assay (ELISPOT), was initially developed to detect and
quantitate individual antibody-secreting B cells. At the time it was
developed, the technique provided a rapid and versatile alternative to
conventional plaque-forming cell assays. Recent modifications have
improved the sensitivity of the ELISPOT assay such that cells producing as
15 few as 100 molecules of specific protein per second can be detected.
These assays take advantage of the relatively high concentration of a
given protein (such as a cytokine) in the environment immediately
surrounding the protein-secreting cell. These cell products are captured
and detected using high-affinity antibodies.

20 The ELISPOT assay utilises two high-affinity cytokine-specific
antibodies directed against different epitopes on the same cytokine
molecule: either two monoclonal antibodies or a combination of one
monoclonal antibody and one polyvalent antiserum. ELISPOT generates
spots based on a colorimetric reaction that detects the cytokine secreted
25 by a single cell. The spot represents a "footprint" of the original cytokine-
producing cell. Spots are permanent and can be quantitated visually,
microscopically, or electronically.

30 The ELISPOT assay involves five specific steps: (1) coating
a purified cytokine-specific antibody to a nitrocellulose-backed microtitre
plate; (2) blocking the plate to prevent nonspecific absorption of any other

proteins, (3) incubating the cytokine-secreting cells at several different dilutions; (4) adding a labelled second anti-cytokine antibody; and (5) detecting the antibody-cytokine complex.

In this invention, the technique is adapted to assay for peptide-specific T-cells that have been pre-sensitised *in vivo* to a particular peptide.

Thus the present invention provides a method of assaying for peptide-specific T-cells, which method comprises providing a fluid containing fresh cells in contact with a surface carrying an immobilised first antibody to a cytokine, adding a peptide to the fluid, incubating the resulting fluid mixture under conditions to cause any peptide-specific T-cells that have been pre-sensitised *in vivo* to the peptide to secrete the cytokine, and detecting any secreted cytokine bound to the immobilised first antibody.

The fresh cells are preferably peripheral blood mononuclear cells (PBMC). They may suitably be taken from a patient known to be suffering, or to have suffered, from an infection with an intracellular pathogen, e.g. a virus. It is a feature of the invention that fresh cells are used, because cells cultured *in vitro* may develop altered characteristics thus reducing the diagnostic value of the assay. The purpose of the assay is to identify or quantitate peptide-specific T-cells e.g. CD8+ or CD4+ cells that have been activated or pre-sensitised *in vivo* to a particular peptide. When the peptide in question is presented to such cells, the cells secrete various cytokines, of which any one may be selected for the purposes of this assay. Preferably the cytokine selected is interferon- γ (IFN- γ).

The assay method involves providing a surface carrying an immobilised first antibody to the IFN- γ or other cytokine. A fluid containing the PBMC or other fresh cells is placed in contact with that immobilised antibody. About 30% of the PBMC are CD8+ cells. In the PBMC of a patient who has recovered from a previous influenza virus infection, about

1 CD8+ cell in 10^5 - 10^6 is a memory cell that has been pre-sensitised to a specific epitope associated with the influenza virus.

The method of the invention involves adding a peptide to the fluid. The peptide may be a known epitope for a well characterised viral infection; or may be a candidate epitope possibly associated with a less well characterised viral infection. The resulting fluid mixture is incubated under conditions to stimulate any peptide-specific T-cells that may have been pre-sensitised to that particular virus-derived peptide *in vivo*. The peptide needs to be of a length, e.g. 7 - 12 and particularly 8 - 10 amino acid residues long, that is recognised by CD8+ cells. It is supposed that the generality of the CD8+ cells (and other PBMC) present the peptide to the small minority of CD8+ cells that may have been pre-sensitised to the peptide. If such activated or pre-sensitised peptide-specific T-cells are present in the test fluid, they respond by secreting IFN- γ or other cytokine which then becomes bound to the immobilised antibody.

It is preferred that the peptide be added in uncombined form to the fresh cells. While it is possible to add cultured cells that have been pulsed with the peptide, this is not necessary when using defined peptide epitopes. The peptides should be added in an amount sufficient to generate an observable signal; a preferred concentration range in the fluid is 0.01 up to 100 μ M particularly 0.5 - 5.0 μ M.

Incubation should be continued for a time sufficient to permit CD8+ cells that have been pre-sensitised *in vivo* to the particular peptide chosen to secrete the IFN- γ or other cytokine. The incubation should not continue for so long that quiescent CD8+ cells have time to become activated by the peptide and start to secrete cytokines. This suggests an incubation time of 4 - 24 hours, more particularly 6 - 16 hours. It is an advantage of the invention that the incubation part of the test can be performed in a single working day or overnight, and without the use of sterile conditions required for cell culture *in vitro*.

During the incubation, any IFN- γ or other cytokine secreted by CD8+ cells becomes bound to the first antibody immobilised on the surface. After incubation, the surface may be washed to remove unbound material. For detection, preferably a labelled second antibody to the cytokine is used. When this is applied to the surface it becomes bound to any cytokine present. The second antibody should preferably recognise a different epitope from the first antibody. One or both of the first and second antibodies should preferably be monoclonal. The label may be any that is conventionally used in the field, including radioisotopes, enzymes to generate colour or chemiluminescence, fluorescent groups or groups for detection by mass spectrometry or refractive index (e.g. by surface plasmon resonance). It is convenient but not necessary to use a labelled antibody, any reagent that binds specifically to the cytokine could be labelled and used. Detection and perhaps quantitation of the label is effected by means well known in the field and appropriate to the nature of the label used.

The assay may conveniently be carried out in a multiwell plate. Each well of the plate has a surface carrying a bound first antibody. To each well is added a fluid containing an appropriate number, e.g. 10^3 - 10^6 of cells. Different peptides and/or controls are added to individual wells of the plate. Cells that secrete a cytokine during incubation show up as spots (spot forming cells or SFCs) and the number or density of these in each well can readily be determined.

The assay technique has a number of advantages over prior known techniques:-

- a) It is quicker and more convenient; the duration of the assay is only 6 hours and thus does not require sterile conditions or technique. Current methods of enumerating precursor effector T cells require *in vitro* culture with the specific antigen and autologous feeder cells in a limiting dilution assay (LDA). The method is laborious and time consuming.

- b) It requires minimal technical equipment and is suitable for field conditions in the tropics and developing countries as well as routine diagnostic laboratories. The LDA, by contrast, requires many peripheral blood lymphocytes, a source of gamma irradiation to inactivate the feeder cells and sterile conditions, as the cells need to be cultured for 1-2 weeks.
- c) It is safe and non-radioactive. In the LDA, however, the cultured cells are assayed in a cytotoxic T cell assay (CTL) assay using the radioactive isotope chromium-51.
- d) It is an immediate *ex vivo* assay. As such it measures effector cells in their natural state without the introduction of unknown biases that occur as cells proliferate *in vitro* culture with antigen and exogenous cytokines.
- e) The assay is performed over only 6 hours; as such it measures peptide-specific effector cells directly, without requiring these cells to proliferate *in vitro*. The short duration of the assay also eliminates the possibility that the cells may be becoming activated *in vitro*; it therefore measures effector function that is present *in vivo*. LDAs require the cells to proliferate many fold; however many effector cells do not proliferate in these conditions and therefore the result of the LDA is often an underestimate of the true number of circulating effectors.

The assay technique is expected to be of value in a number of different ways:-

- i) For research into the mechanisms involved in peptide presentation and recognition and activation. Through the experimental work described in outline below, the inventors have gained insight into the phenotype and effector function of antigen-specific T-cells freshly isolated from peripheral blood.
- ii) For quantifying peptide-specific effectors in HIV-infected individuals direct from peripheral blood.
- iii) For monitoring the progress of, or resistance to, a chronic

infectious disease, for example in response to a drug or therapeutic vaccine. This is expected to be particularly useful for HIV, Hepatitis B and Hepatitis C.

iv) For identifying peptides that may be implicated in a disease state (Epitope mapping), an important preliminary step in the design of a new vaccine. This is expected to be of interest for tuberculosis, malaria and HIV.

v) For monitoring the extent to which a patient, who has suffered from a particular disease such as influenza, may be resistant to future infections.

vi) For monitoring induction and maintenance of CD8+ and CD4+ antigen-specific T cells following immunisation with experimental preventative vaccines, e.g. malaria.

The following examples illustrate the invention.

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EXAMPLE 1

Immunological Memory to Influenza Virus: Ex Vivo Enumeration and Characterisation of Circulating Peptide-Specific CD8+ Activated T Cells in the Memory State

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Subjects were healthy laboratory personnel or healthy adult volunteers, who were HLA typed serologically by complement mediated lymphocytotoxicity. 5 MHC Class I-restricted influenza epitopes were used and are listed in Table 1.

25

96-well PVDF-backed plates were coated with 100 µl of 15 µg/ml of the anti-IFN-γ Mab 1-DIK overnight at 4° or at room temperature for 3 hours. The plates were washed and then blocked with R10 (?) for 1 hour at room temperature. PBMC of the subjects were separated from heparinised whole blood by centrifugation, resuspended in R10 and added in a final volume of 100 µl R10/well to the 96-well PVDF

30

backed microtitre plates. Input cell numbers were usually 5×10^5 per well, and all assays were done in duplicate wells. Peptides were usually added to a final concentration of 1-2 μM , except in one peptide titration experiment where the concentration of the M1 58-66 peptide was diluted to 20 nM. Assays were usually performed for 12-14 hours, but certain assays were performed for 6 hours to confirm that the antigen-specific cells were capable of immediate effector function. Incubation was carried out at 37°C in an atmosphere containing 5% CO_2 . Incubation was arrested by shaking off the contents of the wells and washing. Then 100 μl of 1 $\mu\text{g/ml}$ of a biotinylated second anti-IFN- γ MAB 7-B6-1-biotin (Mabtech, Stockholm, Sweden) was added to the wells and the plates incubated for 3 hours. 100 μl of 1:1000 dilution of streptavidin-alkaline phosphatase conjugate was added to the wells and the plates incubated at room temperature for a further 2 hours. The wells were again washed, and 100 μl of chromogenic alkaline phosphatase substrate diluted 1:25 with deionised water was added to the wells. After a further 30 - 60 minutes incubation at room temperature the wells were washed to terminate the colorimetric reaction. The spots were counted under x20 magnification with a dissecting stereomicroscope.

Results

Using 5 well-defined HLA Class I-restricted influenza epitopes, free peptide was added to a final concentration of 2 μM directly to the freshly isolated PBMC in the ELISPOT assay. For almost all the individuals tested in this way, using epitopes restricted by HLA Class I alleles present in the individual, IFN- γ secreting peptide-specific effector T-cells were detected. Table 1 summarises the responses to these five epitopes. Most of these assays were performed over 12 - 14 hours, and Figure 1 is a bar chart showing the response at different concentrations of PBMC per well. However, to exclude the possibility that memory T-cells

might proliferate or become activated *in vitro* during the course of a 14 hour assay, 6 hour assays were also performed. Peptide-specific SFCs were detected as shown for the same M1 58-56 epitope quantitatively in Figure 2. For a negative control, irrelevant peptides from infectious agents which the donor was not infected were added directly to the fresh PBMC.

Most experiments were performed at final peptide concentrations of 2 μ m. However, responses were still readily detectable when peptide concentrations were reduced down to 0.02 μ m, as shown in Figure 3 for the influenza HLA-A2.01-restricted matrix epitope.

10 Depletion of CD8+ T-cells from fresh PBMC with anti-CD8 antibody-coated magnetic beads completely abrogated the peptide-specific response, confirming that the effectors giving rise to the spots elicited by known Class I-restricted epitopes are CD8+ T lymphocytes. Conversely, depletion of CD4+ cells did not diminish the number of IFN- γ SFCs, 15 indicating that neither CD4+ nor their cytokine products were required for the acquisition or deployment of effector function by the freshly isolated peptide-specific CD8+ T cells. Immediate effector responses were only detected to influenza epitopes restricted by the HLA Class I alleles present in the particular donor being tested; addition of influenza epitopes 20 restricted by HLA Class I molecules not present in the donor never resulted in SFCs. (data not shown).

While expansion of peptide-specific CD8+ effector CTL during acute influenza renders the cells detectable by means of the known 51 Cr release cytotoxicity assay performed with fresh uncultured PBMC, 25 after recovery from the acute illness, such cells are no longer detectable. It appears that this is not because they are absent, but rather because they are present at too low a frequency to be detectable. After recovery from the acute illness, such cells remain detectable by the ELISPOT assay technique of the present invention.

30 Counting the spots under magnification, and comparing this

number to the input number of fresh PBMC gives a measure of the relative frequency of circulating activated peptide-specific CD8+ effectors in peripheral blood. The frequency of IFN- γ -secreting CD8+ effectors for the HLA-A2.1-restricted epitope M158-56 in donor WB was measured by the invention assay (1/15000) and by conventional limiting dilution analysis (LDA) (1/103000).

Table 1. Class I-restricted influenza epitopes recognised by freshly isolated CD8+ effector T cells

Protein	Sequence	MHC class I restriction	No of Responders	No of donors tested
M1 58-66	GILGFVFTL	A2.01	6	6
NP 380-388	ELRSRYWAI	B8	3	4
M1 128-135	ASCMGLIY	B35	2	2
NP 265-273	ILRGSAHK	A3	1	2
NP 383-391	SRYWAIRTR	B27.05	1	1

EXAMPLE 2

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Application to quantifying peptide-specific effectors in HIV-infected individuals direct from peripheral blood

Cryopreserved peripheral blood lymphocytes (PBL) that had been freshly isolated from the peripheral blood of patient 868 were plated out at 50,000 cells per well of a PVDF coated 96 well plate, which had previously been coated with anti-interferon-gamma monoclonal antibody. Duplicate wells were set up for each antigen. Two types of duplicate

20

control wells were used: no peptide and an irrelevant HIV gag epitope restricted through HLA-B8, an HLA allele not present in patient 868.

A range of peptides and their respective naturally occurring variants (previously identified in patient 868) were added directly to the cells at a final concentration of 2 microM. The plate was incubated for 12 hrs at 37°C in 5% CO₂ and developed as previously described (see Example 1). The resulting spots were counted with a x40 dissection microscope. These results are presented in tabular form in Figure 4.

EXAMPLE 3

Identification of CD4+ and CD8+ Epitopes in Secreted Antigens of *M. Tuberculosis*

Mounting evidence points to a protective role for CD8+ cytotoxic T lymphocytes in *Mycobacterium tuberculosis* infection, but *M. tuberculosis*-specific CD8+ T cells have not hitherto been identified in man. Using a reverse immunogenetic approach, the inventors have synthesised an array of candidate Class I MHC-restricted peptides from four immunodominant antigens of *M. tuberculosis*, HSP-65, ESAT-6, MPT-64 and antigen 85. Two of these antigens confer protection on rodents immunised with the respective DNA vaccine constructs. The inventors have screened 75 subjects representing a broad clinical spectrum of *M. tuberculosis* infection. Peripheral blood lymphocytes were stimulated *in vitro* with the peptides and then tested for cytolytic activity in a ⁵¹Cr release assay and for single cell interferon-γ release in an ELISPOT assay. The inventors have identified several octamer and nonamer epitopes from ESAT-6 and antigen 85 in patients and exposed contacts. Certain epitopes are recognised by CD8+ lymphocytes in an MHC Class I restricted manner; others are recognised preferentially by CD4+ T cells. Experiments are underway to demonstrate that these cells recognise naturally processed antigen.

CLAIMS

- 5 1. A method of assaying for peptide-specific T-cells, which method comprises providing a fluid containing fresh cells in contact with a surface carrying an immobilised first antibody to a cytokine, adding a peptide to the fluid, incubating the resulting fluid mixture under conditions to cause any peptide-specific T-cells that have been pre-sensitised to the
10 peptide to secrete the cytokine, and detecting any secreted cytokine bound to the immobilised first antibody.
2. A method as claimed in claim 1, wherein the fresh cells are peripheral blood mononuclear cells.
3. A method as claimed in claim 1 or claim 2, wherein the
15 peptide-specific T-cells are CD8+ or CD4+ cells and the cytokine is IFN- γ .
4. A method as claimed in any one of claims 1 to 3, wherein the peptide is 7 - 12 amino acid residues in length.
5. A method as claimed in any one of claims 1 to 4, wherein the resulting fluid mixture is incubated under non-sterile conditions.
- 20 6. A method as claimed in any one of claims 1 to 5, wherein a second antibody to the cytokine labelled with a detectable moiety is used to detect any secreted cytokine bound to the immobilised first antibody.
7. A method as claimed in any one of claims 1 to 6, wherein the peptide is a known epitope.
- 25 8. A method as claimed in any one of claims 1 to 7, wherein the fresh cells are taken from a patient known to be suffering, or to have suffered from, infection with an intracellular pathogen.
9. A method as claimed in any one of claims 1 to 8, performed to monitor progress of HIV infection.

10. A method as claimed in any one of claims 1 to 8, performed to monitor the effect of a vaccine.

11. A method as claimed in any one of claims 1 to 8, performed to determine a pathogen-derived epitope targeted by CD4+ or CD8+

5 T cells.

Figure 1

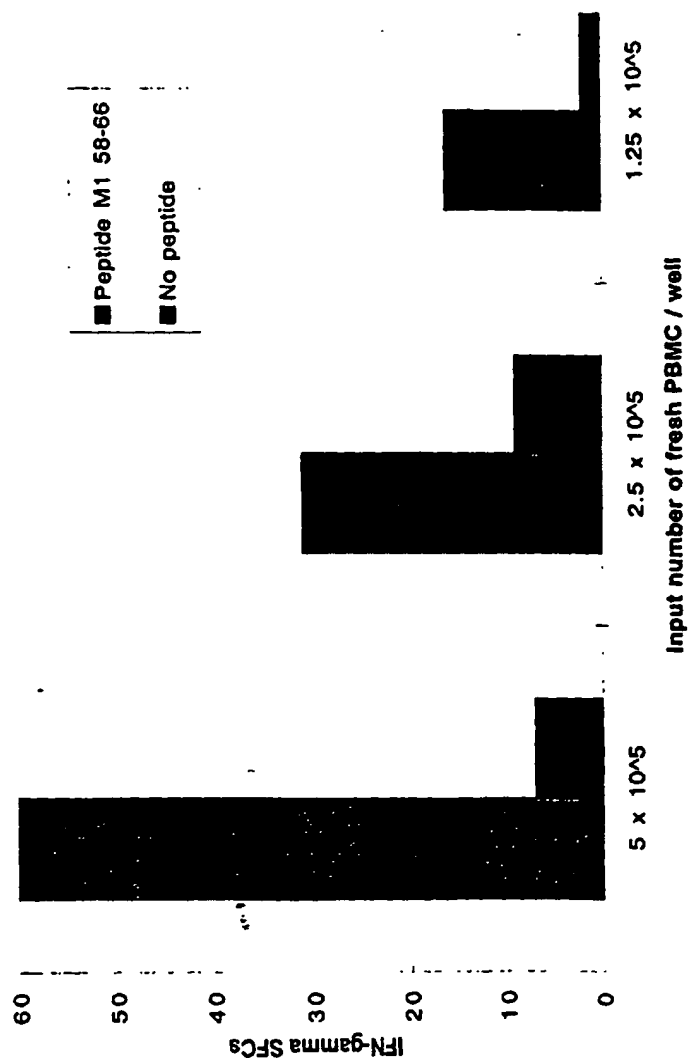


Figure 2

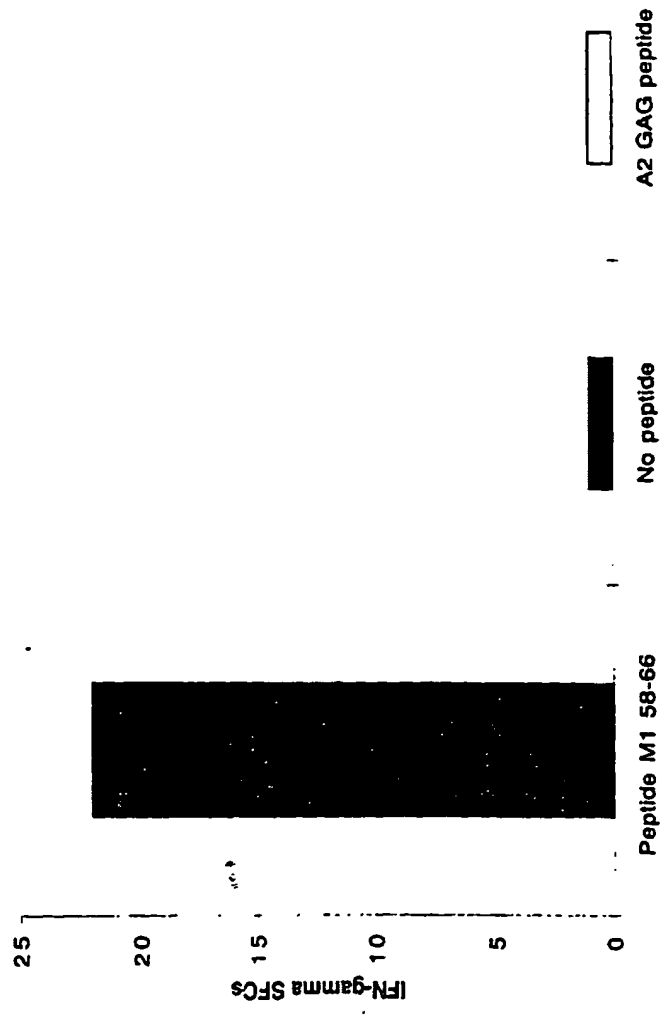
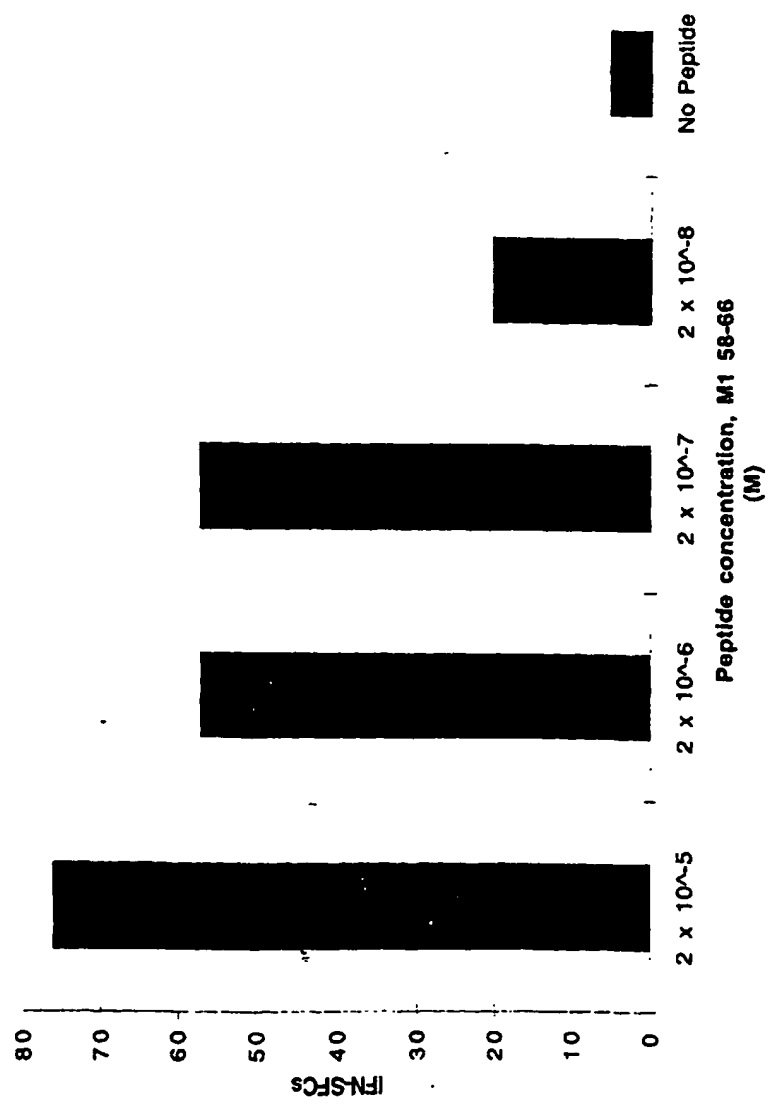


Figure 3



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